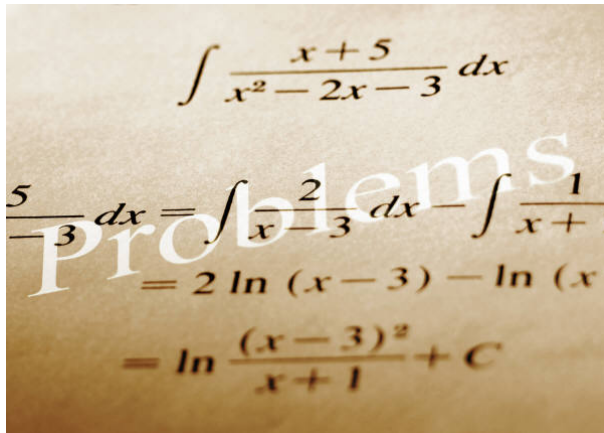


Use of ISS for Validation of Advanced Power Systems for Exploration

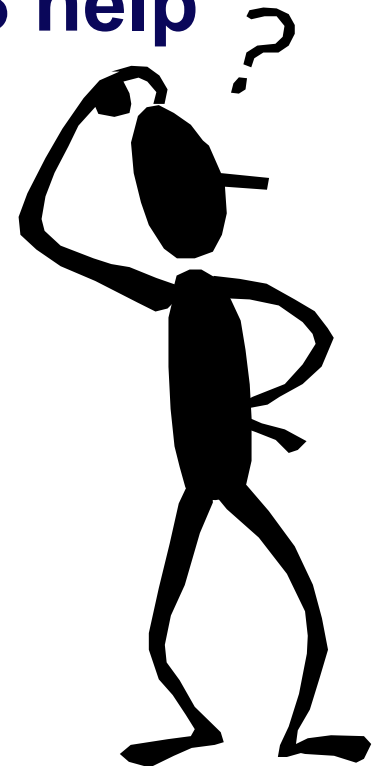
**Presented to
1st Annual ISS Research and
Development Conference
Denver, Colorado
June 27, 2012**

**James F. Soeder
Raymond F. Beach
NASA Glenn Research Center**



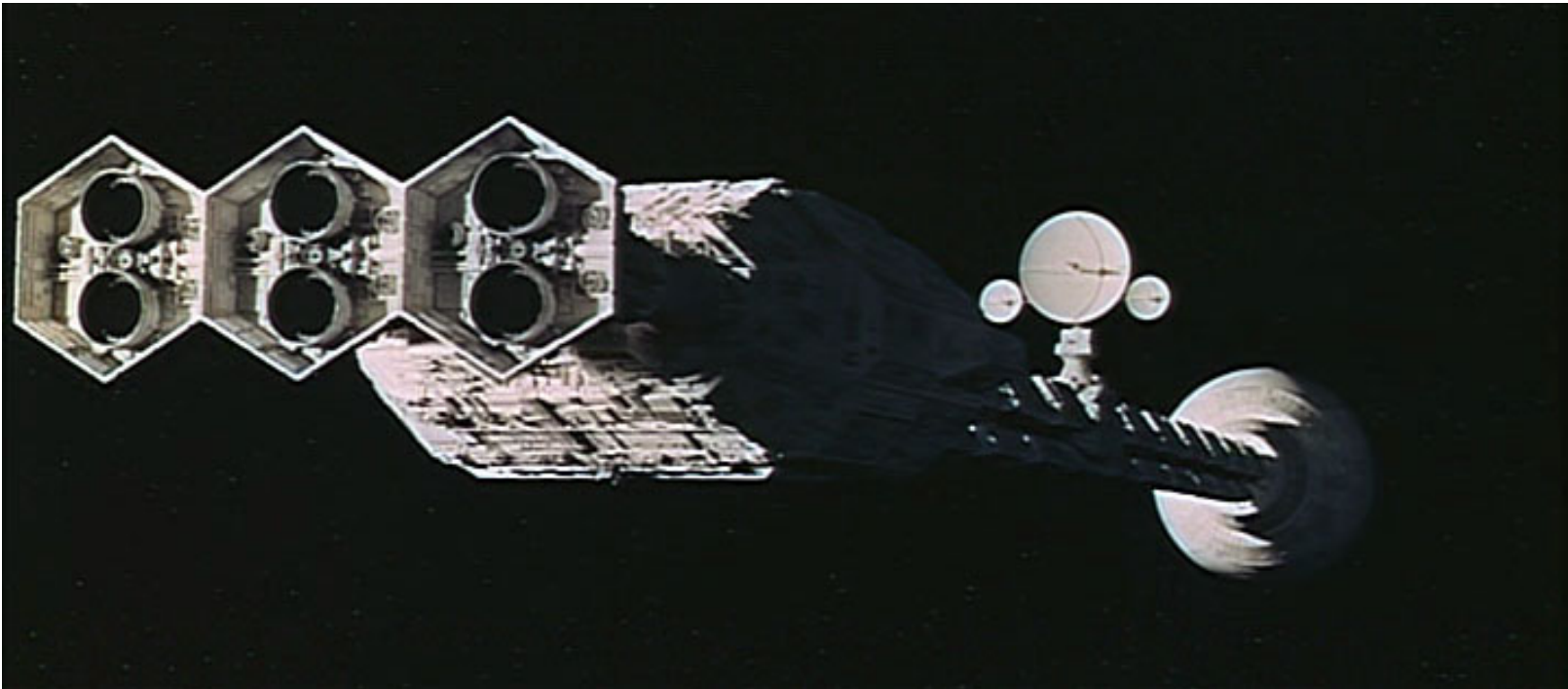

$$\int \frac{x+5}{x^2-2x-3} dx$$
$$\frac{5}{-3} dx = \int \frac{2}{x-3} dx - \int \frac{1}{x+1}$$
$$= 2 \ln(x-3) - \ln(x+1)$$
$$= \ln \frac{(x-3)^2}{x+1} + C$$

So what are the power issues in deep space exploration and how can the ISS help

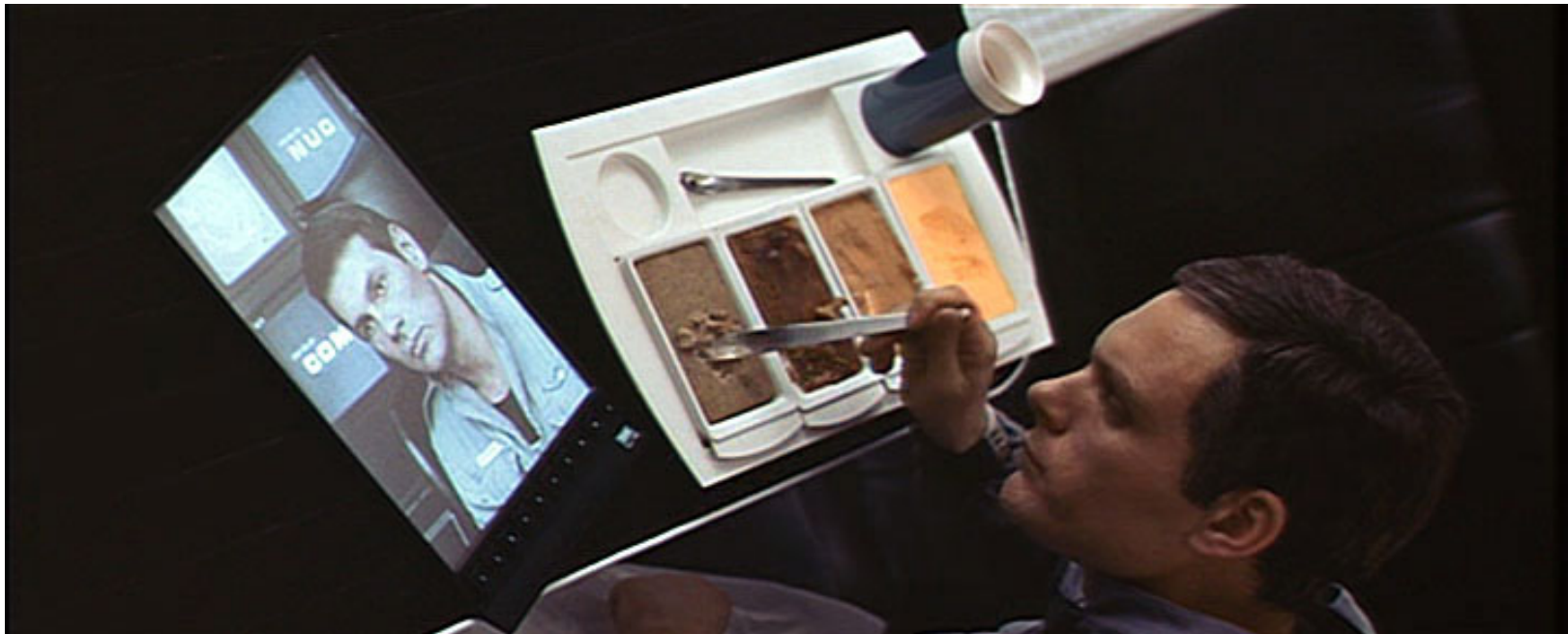




**Let's travel back and see how popular Sci-Fi looked
at deep space exploration**



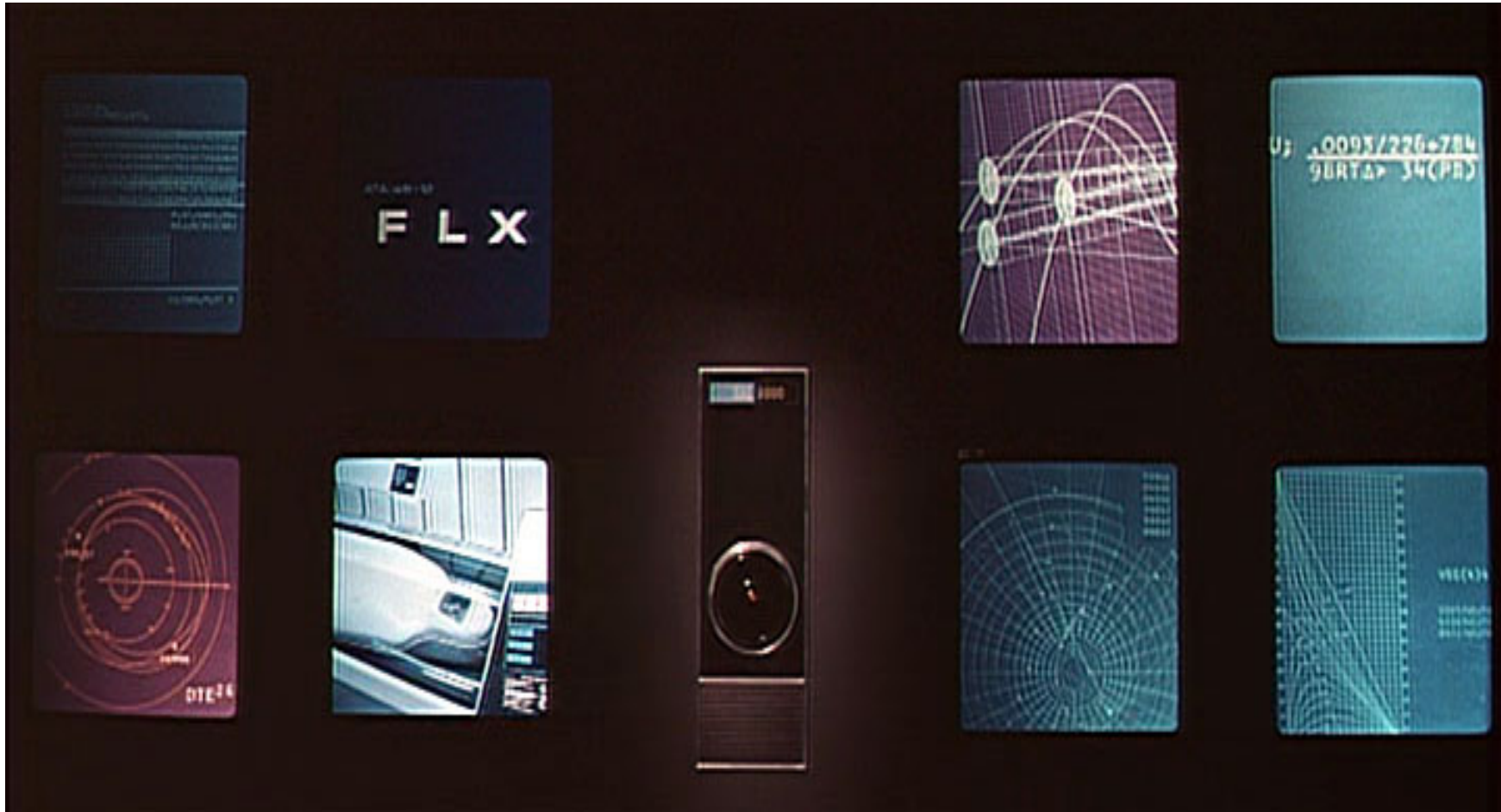
Today we are looking at deep space exploration similar to the mission to Jupiter in the movie 2001 by Spaceship “?”



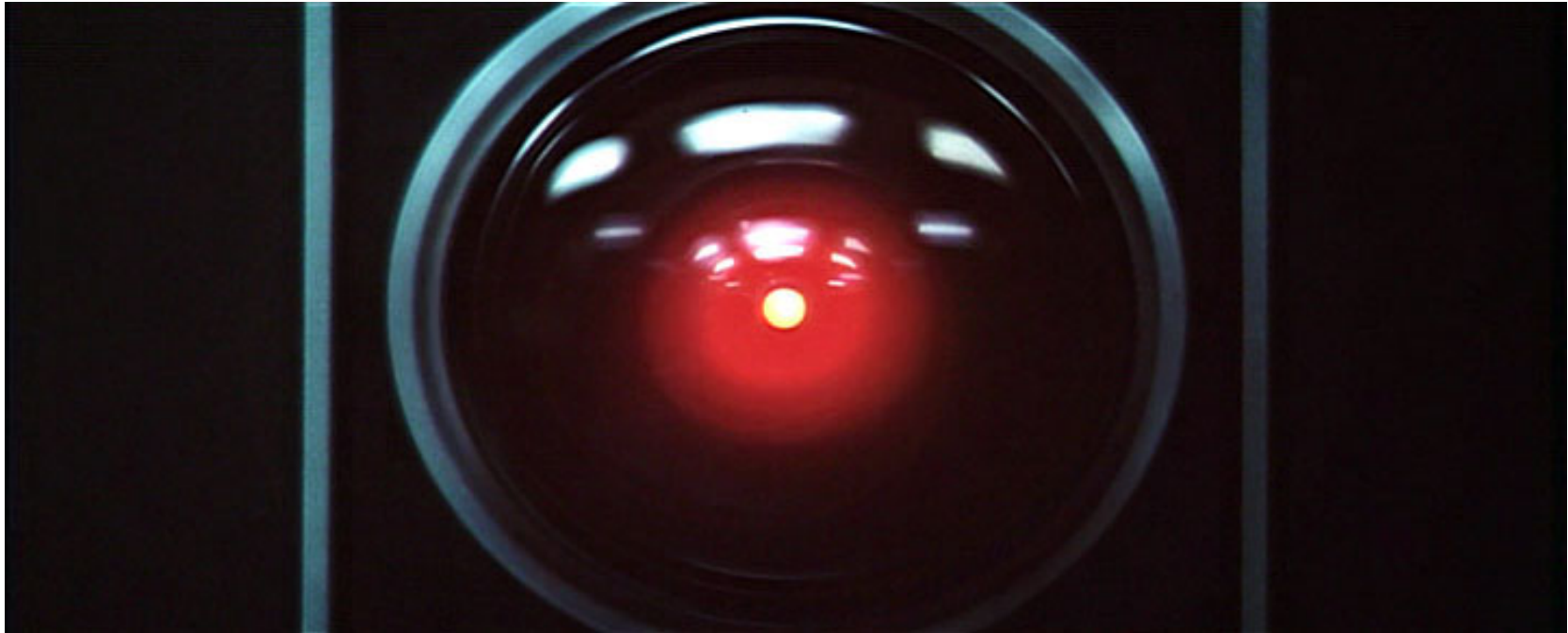
Communication and hence control from Earth was done with long time delays



**The operation of the spacecraft was routine and mundane
for the astronauts – autonomous operation
of core systems**



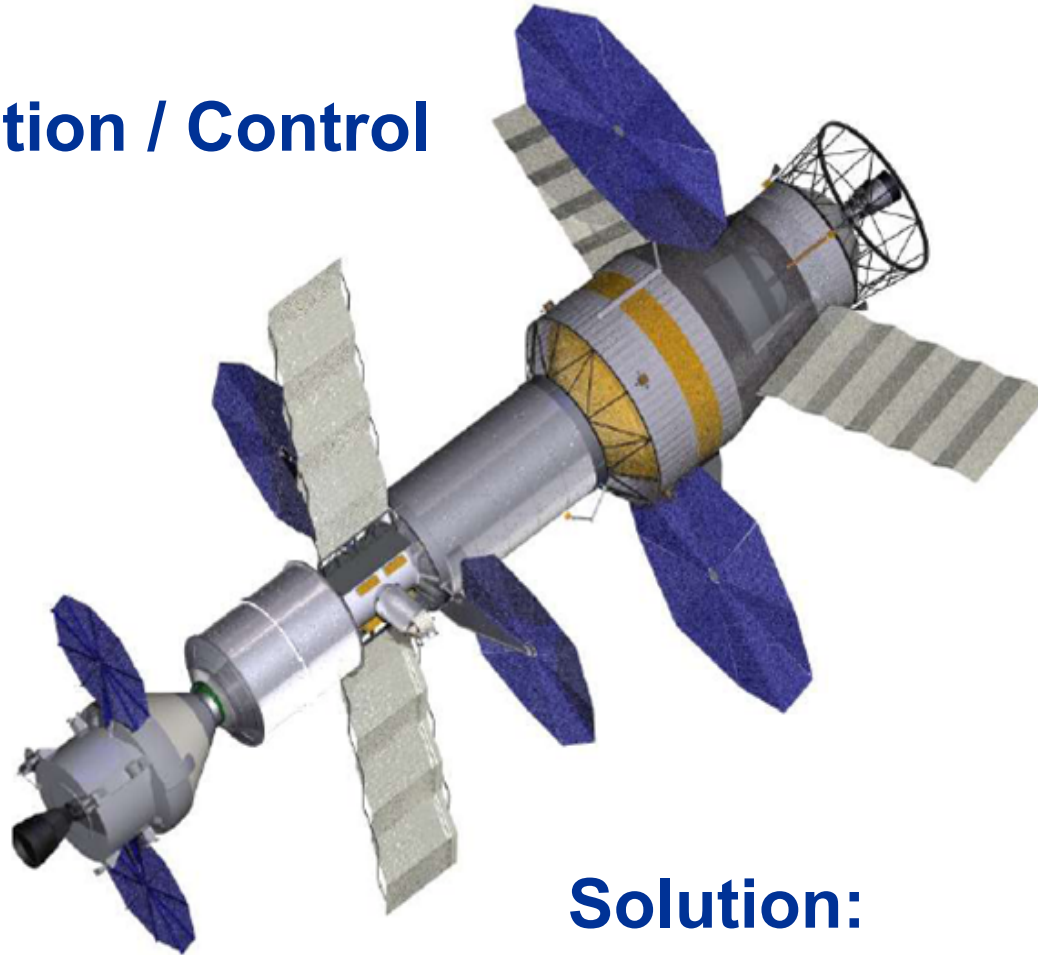
To accomplish this the ship was totally automated



But we want the systems to be helpful and respond to Cntrl-Alt-Delete



Problem:
Communication / Control
delay



Solution:
Autonomous Control

**NASA's ambition for deep space exploration requires
the capabilities recognized long ago**

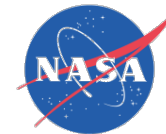


Utilizing ISS as an engineering test platform can facilitate the vision for an automated future for selected core systems



A Little Review of ISS Power





ISS Power System Characteristics

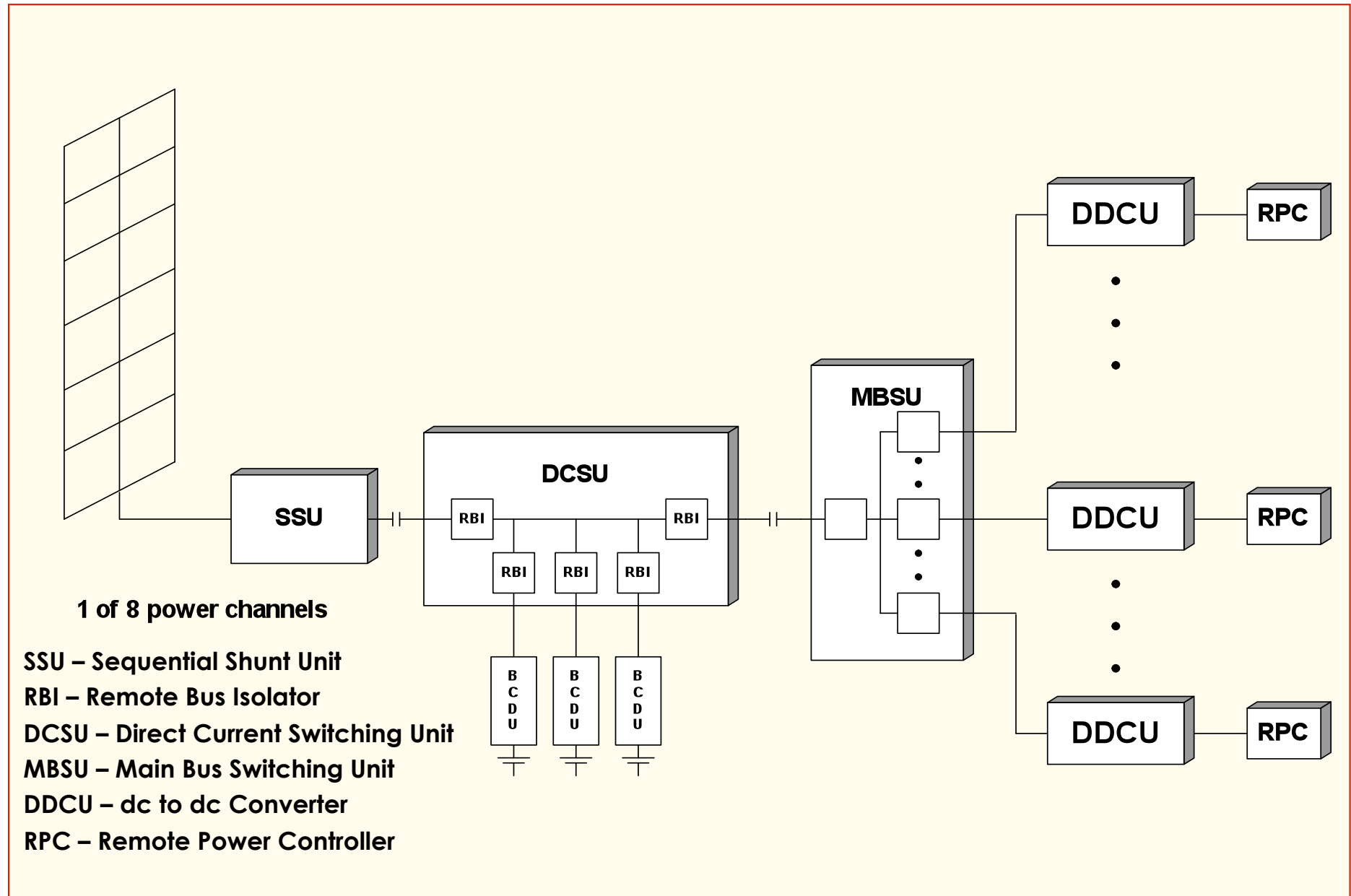
- **Power 75 kW average**
- **Eight independent power channels -- 9.75 kW**
- **Solar array power**
 - **200+ kW silicon arrays**
- **NiH battery storage**
 - **1900 amp*hrs**
- **Distribution**
 - **116 – 170 V primary**
 - **120 V secondary**

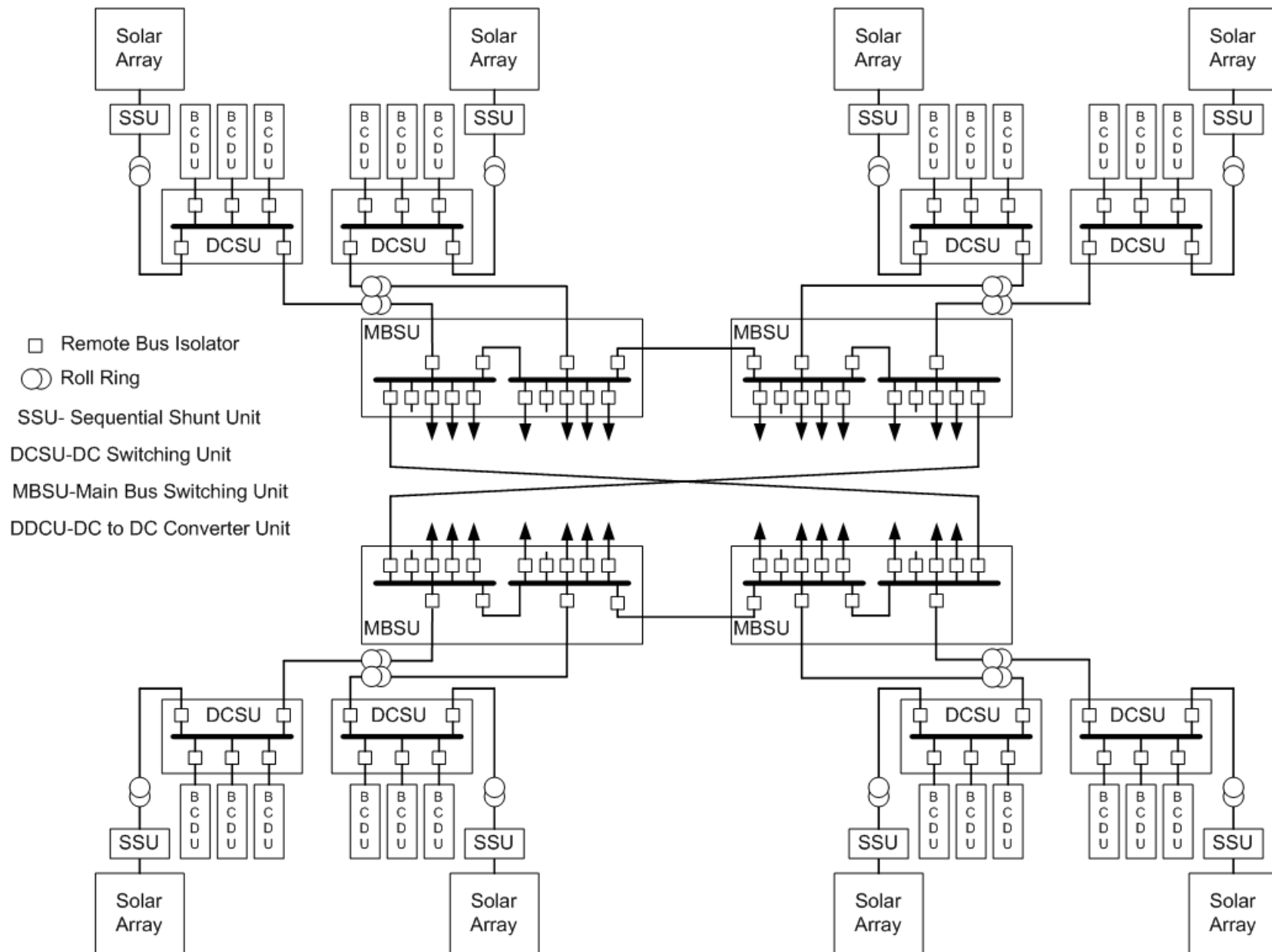


ISS is the largest power system that currently flies in space

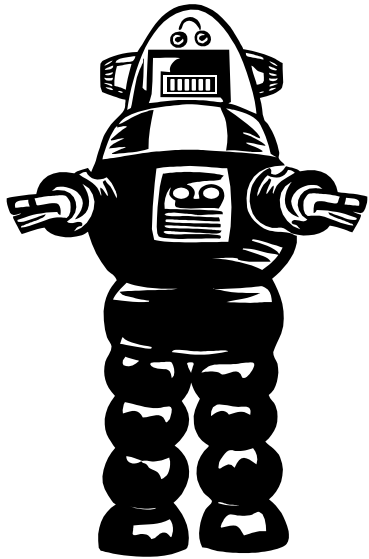


ISS Power Architecture



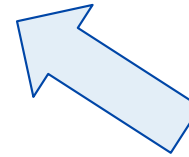


The ISS power system is a power grid

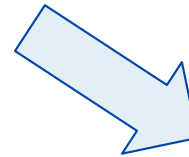


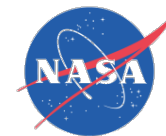
Autonomous Future



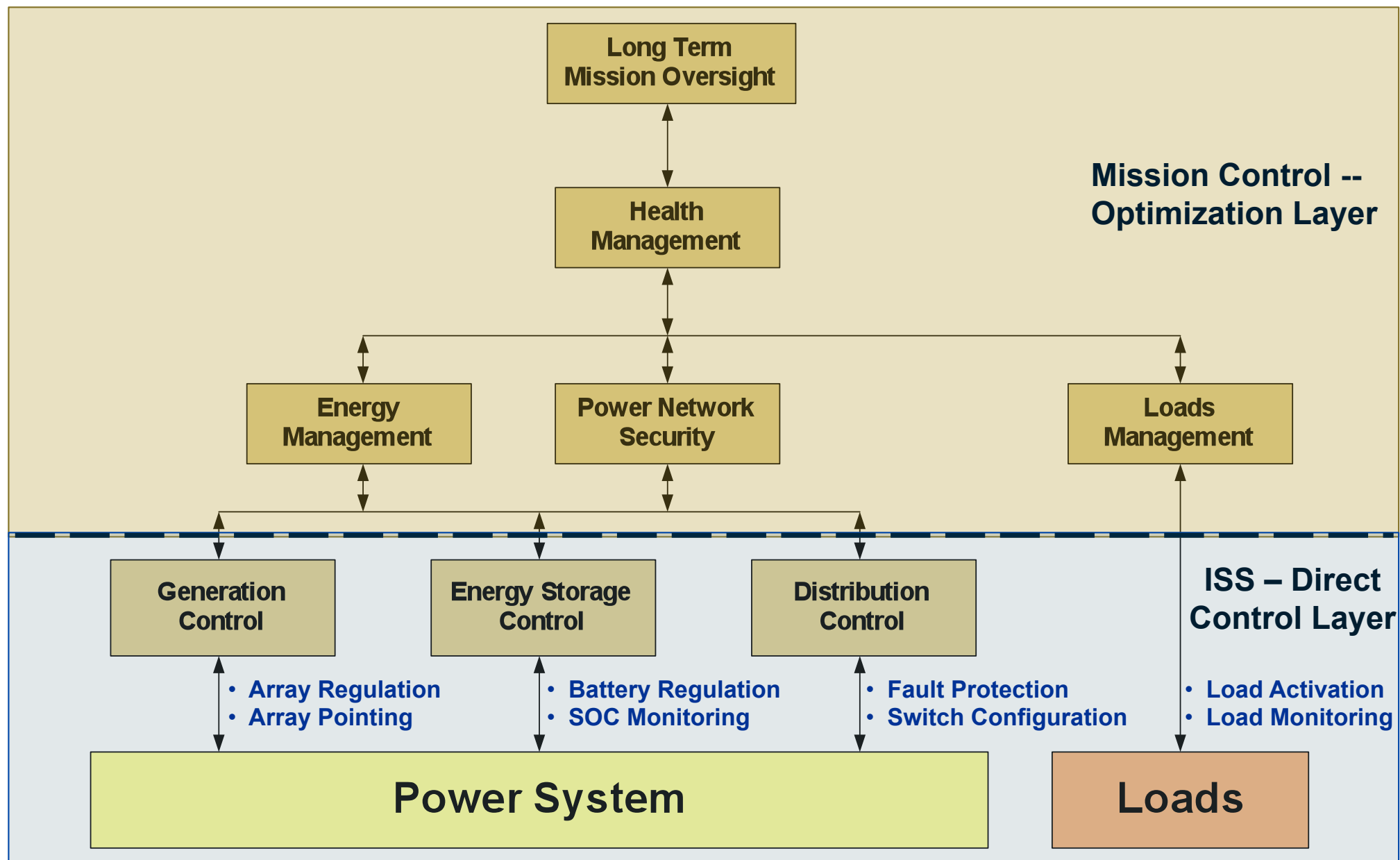


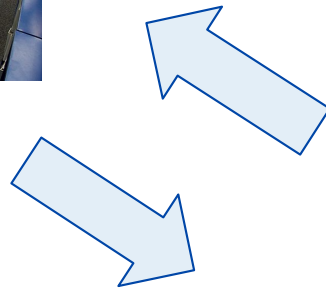
ISS relies on continuous real-time support of mission control





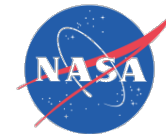
Current ISS Power System Control Functionality



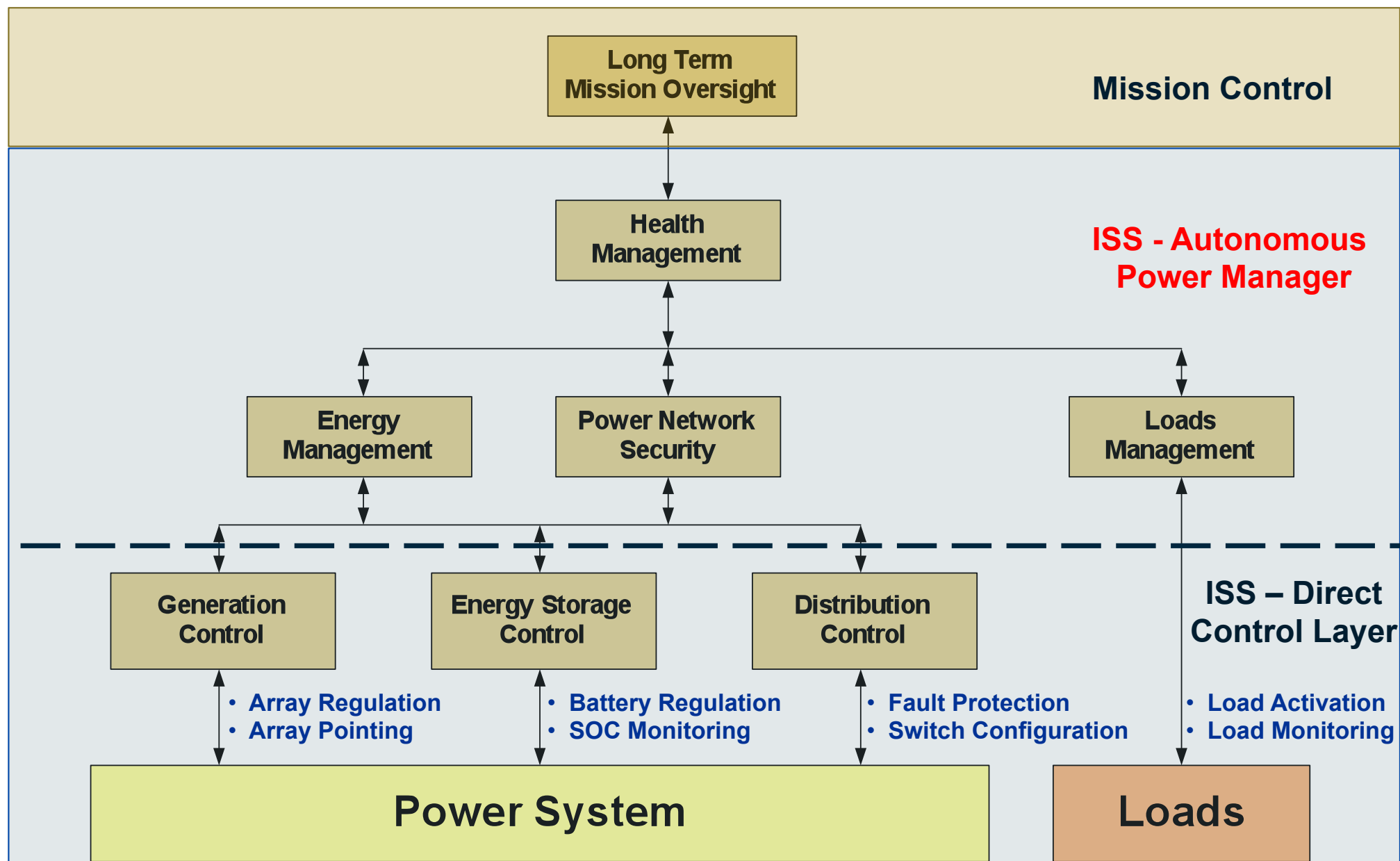


Future space needs to have less dependence on the ground and more on internal intelligence. The ISS can be a pathfinder





Future ISS Power with Autonomous Power Manager





So How Do We Proceed?





Incremental Development & Demonstration Approach

Direct Control

Direct Control

Energy Mgmt.

Direct Control

Energy Mgmt.

Load Mgmt.

Direct Control

Energy Mgmt.

Load Mgmt.

Pwr. Net. Sec.

Direct Control

Energy Mgmt.

Load Mgmt.

Pwr. Net. Sec.

Health Mgmt.



Phase 0

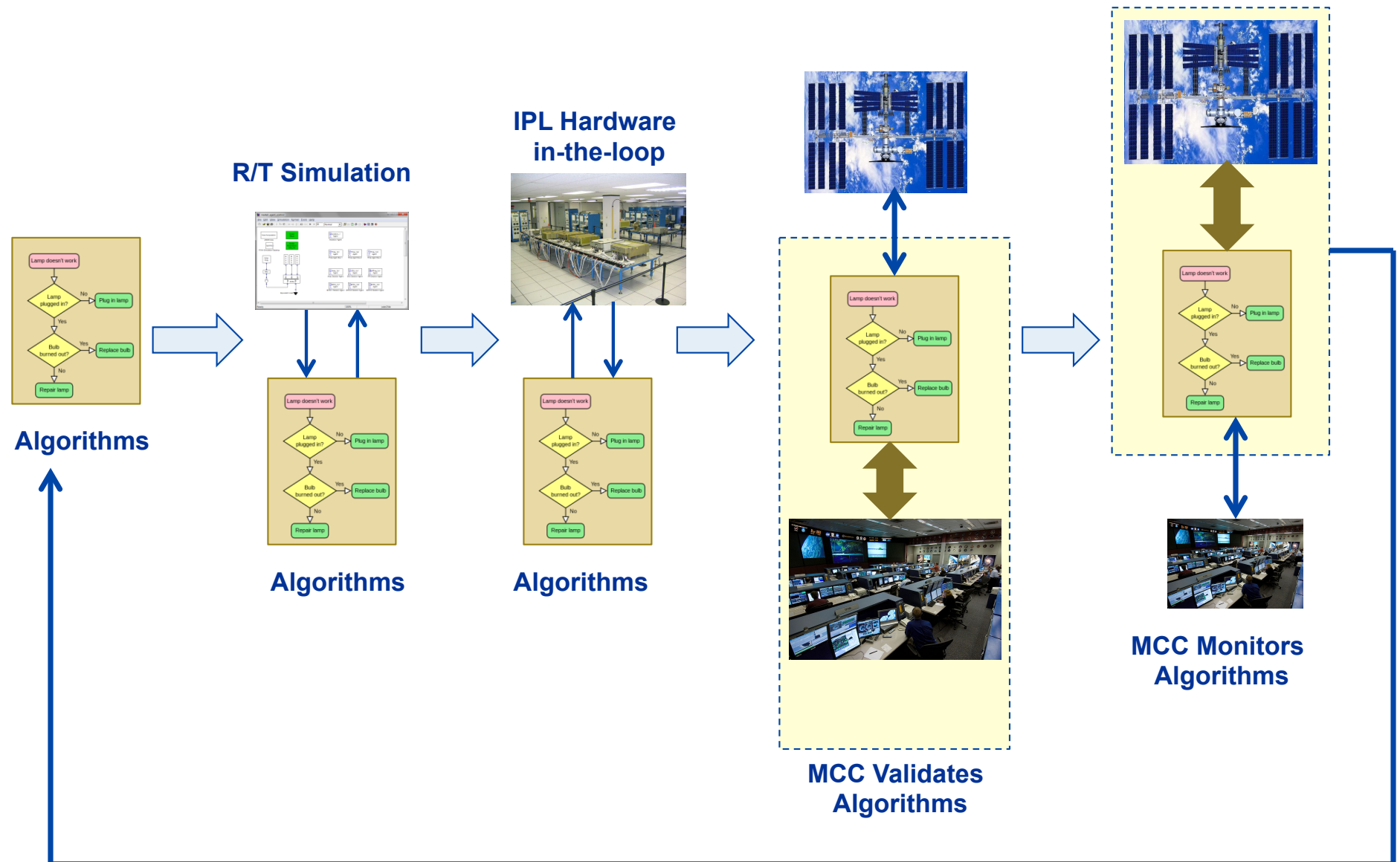
Phase 1

Phase 2

Phase 3

Phase 4

Development Approach





Can we Apply Leverage to Achieve our Objectives?





Commonality with Future Terrestrial Grids



Exploration Power vs Terrestrial Power

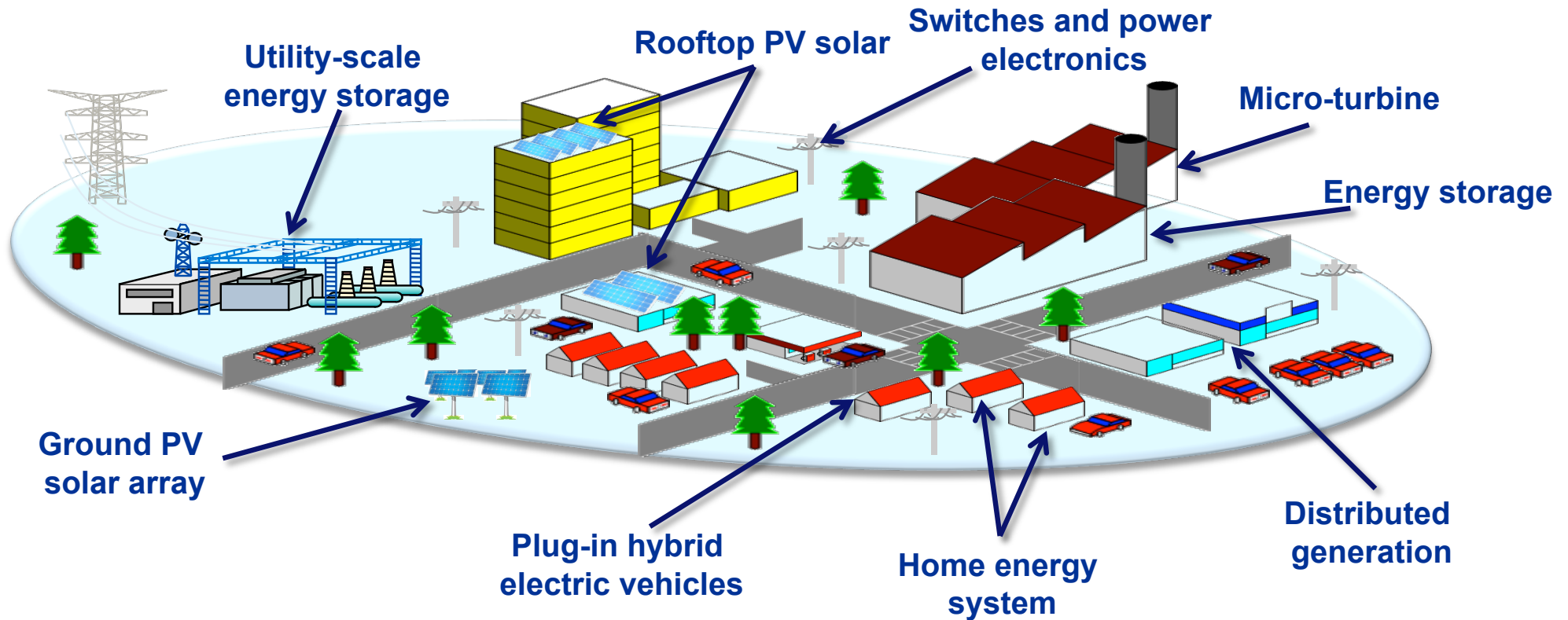


Exploration Power

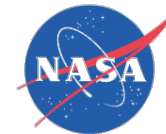
Terrestrial Power

X	Automated control for operations management, fault detection and system reconfiguration	X
X	Increased power demands	X
X	Incorporation of large amounts of distributed energy storage	X
X	Seamless accommodation of Variable / Peak load demand	X
X	Failure diagnostics and prognostics for power components	X
X	Utilization of diverse power sources (renewables)	X

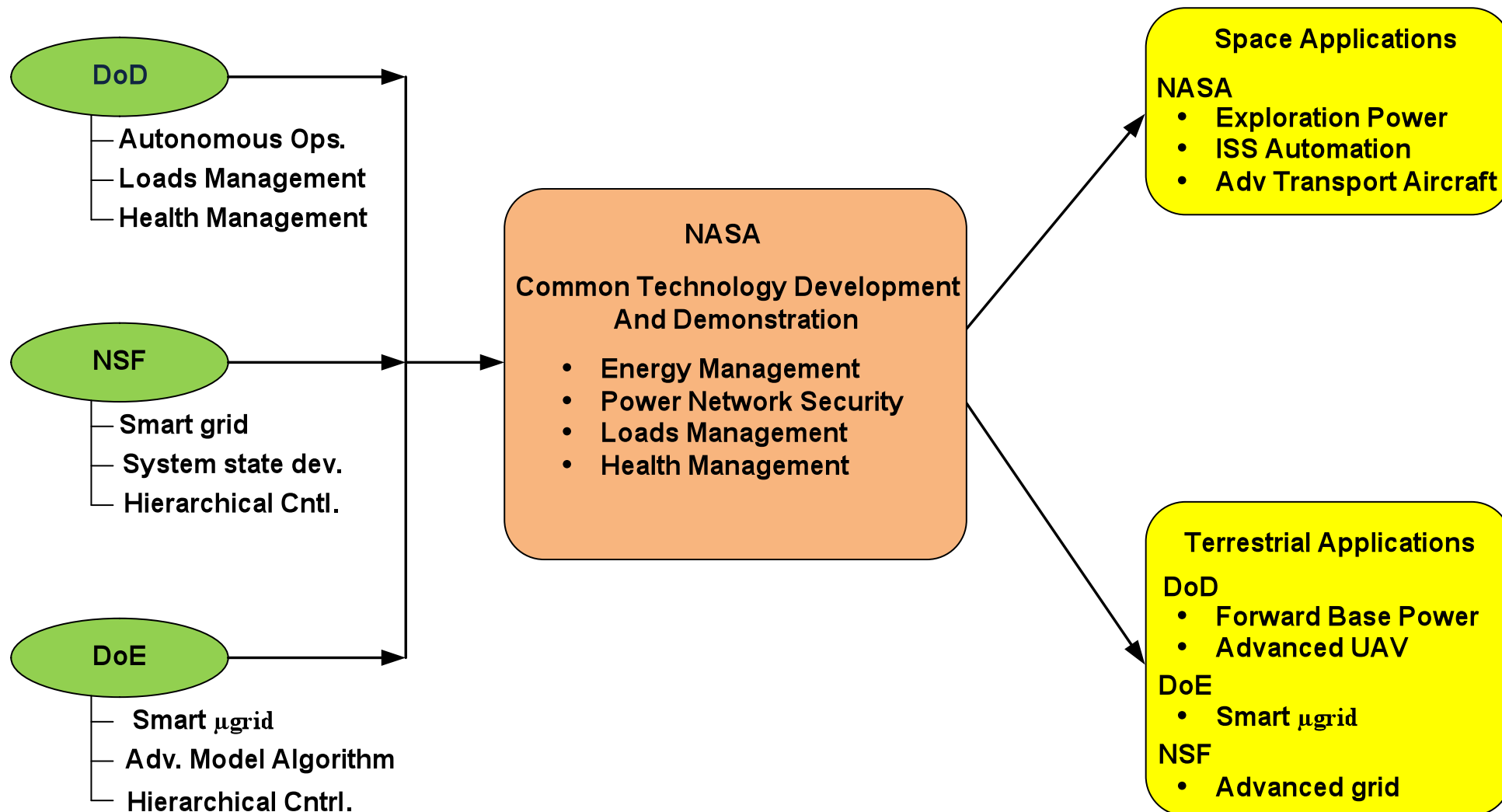
What We Learn on ISS Can be Applied on Earth



The distributed control of micro-grids proposed for modernization of the US Power Grid has automation issues similar to the ISS



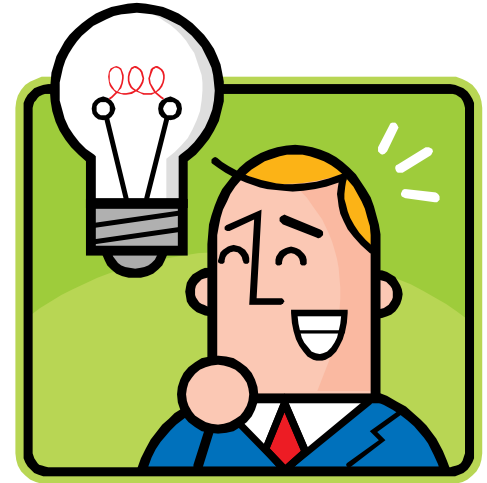
Partnership Approach





Wrap-up

- **We need automated systems for long term operation far from earth**
- **We can use the ISS to incrementally develop and demonstrate capability**
- **We can leverage other expertise and funding (Smart Grid etc.) to achieve our goals**





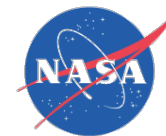
References

- **2001: A Space Odyssey Internet Resource Archive**

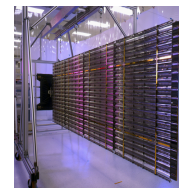
<http://www.palantir.net/2001/gallery/mission.html>



Back-up Slides



Energy Management



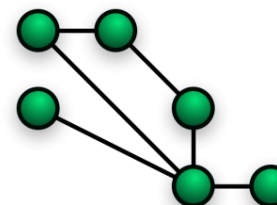
Control power generation and storage

Load Management



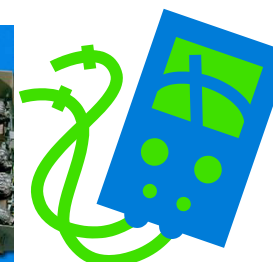
Schedule housekeeping, experiments, etc.

Network Security

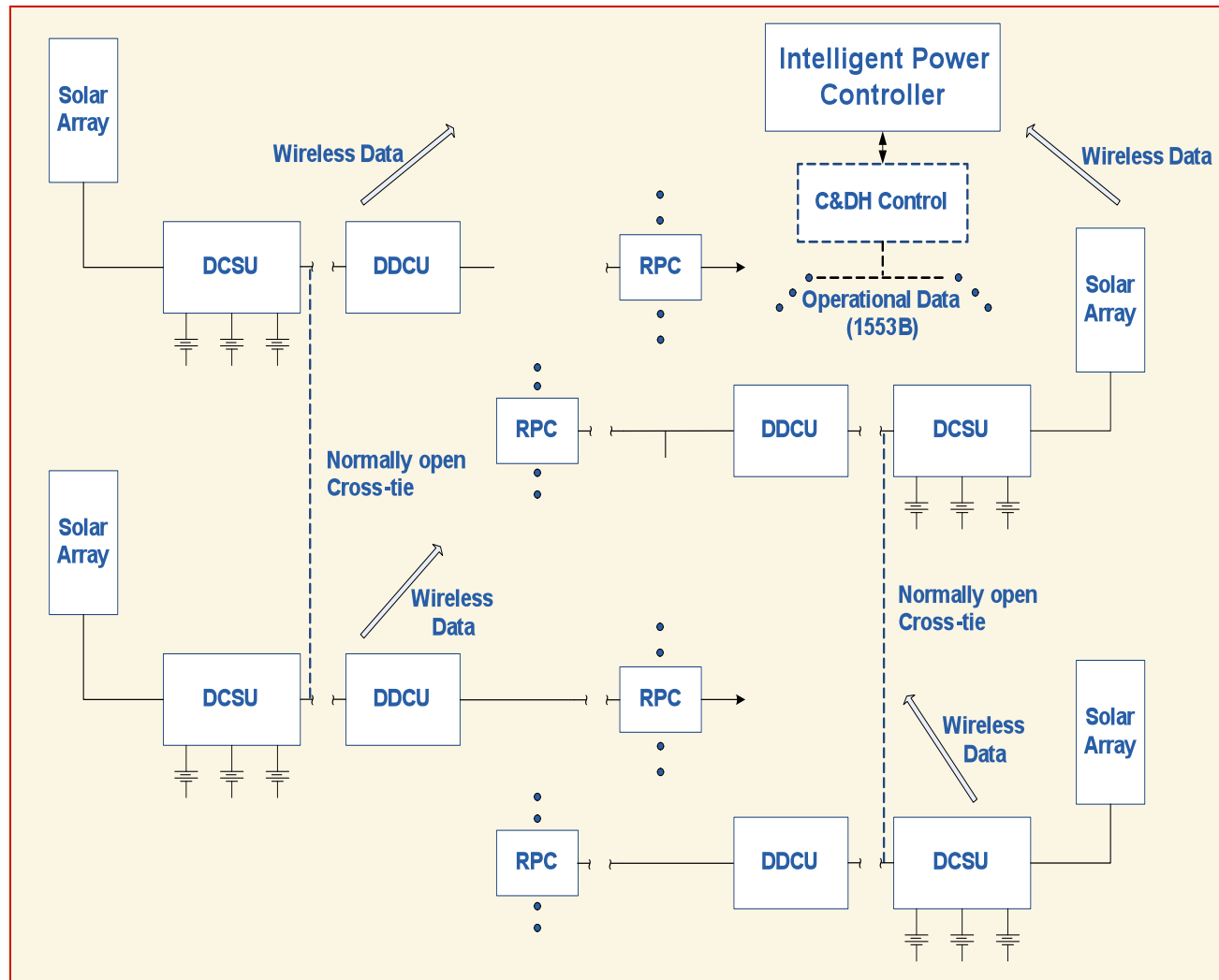


Optimize and control the configuration of the distribution network

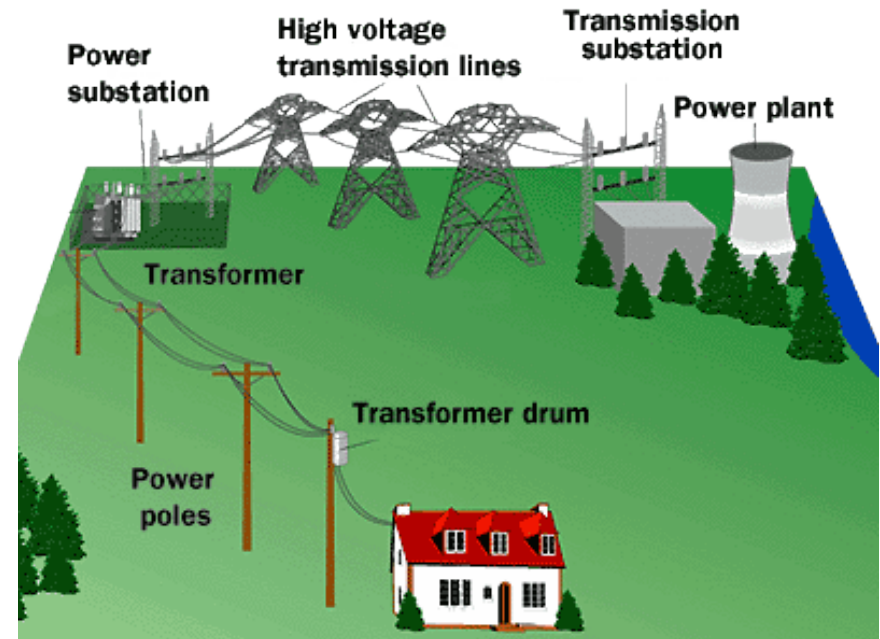
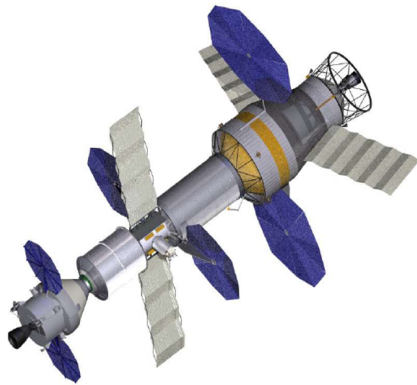
Health Management



Diagnose the state-of-health of ORUs



**To implement on ISS,
the current C&DH system is unchanged and wireless
sensors plus an Intelligent Power Controller is added**



Terrestrial

Exploration

The power system development issues for Exploration are common with that Terrestrial “Smart Grid”